Dynamic Query

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Switching for Complex Event

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Processing on FPGAs

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Complex event processing (CEP) is a new computing paradigm to deal with it.

Applications: Real-time data processing
- Financial trading
- NW traffic analysis
- Health care

Employed: Complex Event Processing

- Complex event processing (CEP) is a new computing paradigm to deal with it.
- CEP handles series of data on-the-fly.

Target system
Throughput requirement has surpassed capability of software

Target System: FPGA-based Complex Event Processing
Functions to develop

Requirements for FPGA-based CEP

i. Reduce loss by Increasing reliability, availability and serviceability
   Example: Remove buggy trading query to prevent loss

ii. Increase profit through changing functions at run-time
    Example: Switch to most appropriate trading queries

Function to develop: Online query switch
Replacing functions at run-time
Motivating example – Switching trading algorithms

- **VWAP algorithm**
- **Historical Volatility Algorithm**

Cost per stock ($)

- **Cost per stock (VWAP only)**
- **Cost per stock (VWAP then HV)**

Profit of 12,350$/day
1. Server shutdown is required, OR
2. Inconsistent outputs during switch

Issues of conventional technique

Writing new query by partial reconfiguration

1. Old query
2. Partial-reconfiguring
3. New query
Requirements 2: Consistent outputs

1. No gap
2. Old results and new results are not disordered

Results of old query
\[ p_1 \rightarrow p_2 \rightarrow p_3 \rightarrow p_4 \]

Results of new query
\[ q_1 \rightarrow q_2 \]

Results for output

(a) \[ p_1 \rightarrow p_2 \rightarrow q_1 \rightarrow q_2 \] Good: Ideal switch

(b) \[ p_1 \rightarrow q_1 \rightarrow q_2 \] Bad: gap

(c) \[ p_1 \rightarrow p_2 \rightarrow q_1 \rightarrow p_3 \] Bad: disorder

Time
Approach

1. Running old and new query simultaneously
2. Select new query results in a timely manner

(1) Run old query
(2) Configure new query
(3) Run new and old query in parallel
(4) Select and output new results
Architecture of Dynamic Reconfigurable CEP

Event input (10GbE x2)

Event processing part

Query logic

Query logic

Control input (PCIe)

Query Manager

Output Versioning Network

Event output (PCIe)

Function of Query manager

This work
(a) Manage logic area usage and prepare unused area

(b) Configure new query and startup module

(c) Make old query and new query in parallel

(d) Stop and reclaim logic
(1) Attach query ID and version number to query result

Old query has the same ID as, smaller version number than new query

(2) Drop results with smaller versions by comparing version numbers of two results which meet in the merge tournament

(3) Drop remaining results with smaller versions by consulting record of largest version ever passed
Test system for Dynamic Reconfigurable CEP

Evaluation of online query switch
The diagram illustrates the relationship between the VWAP algorithm and the Historical Volatility Algorithm. It shows two distinct phases.

1. **VWAP Phase (0-17):**
   - The diagram indicates that Ver. 1 indicates VWAP is running.
   - The VWAP result is shown as a blue line.

2. **HV Phase (18-37):**
   - The diagram indicates that Ver. 2 indicates HV is running.
   - The HV result is shown as a red line.

The query switch is validated at the end of the cycle.
Throughput of Output Versioning Network

Throughput (Gbps)

- **Output versioning Network**
- **Conventional technique**

**Target**: 20 Gbps (156.25MHz x 128-bit)

- Achieves the target
  - 96% increase

- Throughput:
  - 30.09 Gbps
  - 15.36 Gbps

**Number of Input ports**
(Number of queries running on one FPGA)
1. Online query switch on FPGA-based CEP system is developed
   • Server shutdown is not allowed
   • Outputs during query switch should be consistent

2. Query Manager and Output Versioning Network is proposed to solve the consistency issue
   • Run old query and new query in parallel
   • Select results to output from old and new query results in a timely manner

3. Online query switch is validated on FPGA board

4. OVN achieves target clock frequency